| AD NUMBER |
| --- |
| AD348082 |
| CLASSIFICATION CHANGES |
| TO: unclassified |
| FROM: confidential |
| LIMITATION CHANGES |
| TO: Approved for public release, distribution unlimited |
| FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 31 JAN 1964. Other requests shall be referred to Naval Research Lab., Washington, DC. |
| AUTHORITY |
| NRL ltr, 4 Dec 1996; NRL ltr, 4 Dec 1996 |

AD-348082

UNITED STATES GOVERNMENT

# memorandum

7103/143

DATE: 4 December 1996

FROM: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF. (a) FOR DECLASSIFICATION

TO: Code 1221.1

VIA: Code 7100

REF: (a) NRL Confidential Report #1498 by R.H. Ferris, 31 Jan 1964

1. Reference (a) is a description of the modifications made to improve the acoustic power output of the ARTEMIS transducer. Reference (a) also reports on the results of tests conducted on the modified transducer element. The ARTEMIS program was an experimental research program at low frequencies (400 Hz) to detect and track submarines. The program was not fully completed and never reached operational utilization.

2. The technology and equipment of reference (a) have long been superseded. The current value of this report is historical.

3. Based on the above, it is recommended that reference (a) be declassified and released with no restrictions.

Burton G. Hurdle

BURTON G. HURDLE
Acoustics Division

CONCUR:

L. Bruce Palmer 12/5/96

EDWARD R. FRANCHI Date
Superintendent
Acoustics Division

[redacted]

AD 348082

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION ALEXANDRIA VIRGINIA

[redacted]

[redacted]

AD- 348082

SECURITY REMARKING REQUIREMENTS

DOD 5200.1-R, DEC 78

REVIEW ON 31 JAN 84

[redacted]

[redacted]

NRL Memorandum Report 1498

# PROJECT ARTEMIS ACOUSTIC SOURCE

## CHARACTERISTICS OF THE TYPE TR-11F TRANSDUCER ELEMENT


R. H. Ferris

Electrical Applications Branch
SOUND DIVISION





January 31, 1964



U. S. NAVAL RESEARCH LABORATORY
Washington, D.C.


[redacted]

[redacted]

[redacted]



[redacted]

[redacted]

CONTENTS





[redacted]

CONFIDENTIAL

## DISTRIBUTION

Chief of Naval Operations

- Op-03EG
- Op-32
- Op-07
- Op-70
- Op-71
- Op-714

Office of Naval Research

- Code 467

Bureau of Ships

- Code 370
- Code 688

U. S. Navy Electronics Laboratory

U. S. Navy Underwater Sound Laboratory

U. S. Navy Underwater Sound Reference Laboratory

Arthur D. Little, Inc., Acorn Park
Cambridge 40, Massachusetts

Hudson Laboratories, Columbia University
145 Palisade Street, Dobbs Ferry, New York

- Dr. A. Berman

Massa Division, Cohu Electronics, Inc.
5 Fottler Road, Hingham, Massachusetts

- Mr. Frank Massa

DDC, Alexandria, Va.

- Attn TIPDR

## DISTRIBUTION

| | |
|---|---|
| **Chief of Naval Operations** | |
| Op-03EG | 2 |
| Op-32 | 1 |
| Op-07 | 1 |
| Op-70 | 1 |
| Op-71 | 1 |
| Op-714 | 1 |
| **Office of Naval Research** | |
| Code 467 | 11 |
| **Bureau of Ships** | |
| Code 370 | 2 |
| Code 688 | 2 |
| U. S. Navy Electronics Laboratory | 2 |
| U. S. Navy Underwater Sound Laboratory | 2 |
| U. S. Navy Underwater Sound Reference Laboratory | 1 |
| Arthur D. Little, Inc., Acorn Park<br>Cambridge 40, Massachusetts | 1 |
| Hudson Laboratories, Columbia University<br>145 Palisade Street, Dobbs Ferry, New York | 10 |
| Dr. A. Berman | |
| Massa Division, Cohu Electronics, Inc.<br>5 Fottler Road, Hingham, Massachusetts | 1 |
| Mr. Frank Massa | |
| DDC, Alexandria, Va. | |
| Attn TIPDR | 20 |

## ABSTRACT

Four Massa TR-11C transducer elements, of the type used in the ARTEMIS acoustic source, were mechanically and electrically modified to realize an increased power handling capability and to facilitate a parallel electrical connection of elements in an array. The modified elements, designated type TR-11F, were fitted with new springs designed to operate continuously with cyclic deflections of 22 mils peak to peak replacing the original springs which had a maximum safe deflection amplitude of approximately ten mils peak to peak. The original magnet coils were replaced with coils having a larger number of turns of smaller wire. The resulting increased impedance facilitates a parallel connection of elements in that six parallel connected TR-11F elements would have the same impedance as six series connected TR-11C elements. The present ARTEMIS source utilizes a configuration of parallel electrical connection to groups of six series connected elements. The modification also incorporates an altered air gap configuration and special instrumentation to permit measurements of spring deflections.

This report describes tests in which the four modified elements were operated with a water load at the maximum design spring deflection for approximately 10,000,000 cycles.

Mechanical, electrical and acoustic measurements obtained during and following the endurance tests indicated that the elements were not damaged by operation at this level.

## PROBLEM AUTHORIZATION

ONR RS 046
NRL problem 55S02-11

## PROBLEM STATUS

This is a final report on one phase of this project. Work is continuing.

## INTRODUCTION

The Massa type TR-11F variable reluctance transducer element is a modification of the Massa TR-11C element which is presently employed in the ARTEMIS acoustic source. The modification consists of a change in the spring design, in the magnet coil windings, and the air gap configuration. The mechanically improved springs have been designed for a maximum periodic deflection of 28 thousandths of an inch peak to peak without fatigue failure. The new magnet coils have an electrical impedance which is 36 times that employed in the TR-11C elements, thus facilitating a parallel electrical connection of elements in a multielement array. The present configuration of the ARTEMIS source employs TR-11C elements with a parallel electrical connection of groups of six series connected elements. The impedance of the TR-11F elements is such that six parallel connected TR-11F elements have the same impedance as six series connected TR-11C elements. A completely parallel array of TR-11F elements would have the same impedance as the present ARTEMIS array. The magnetic air gap has been modified to a non-uniform configuration which maintains the same magnetic reluctance as in the TR-11C elements but mechanically restricts the spring deflection to approximately 22 thousandths of an inch peak to peak. The new spring and air gap configurations are illustrated in figure 1.

Tests of four TR-11F elements were conducted during the period 13 - 26 November 1963 at the U. S. Naval Research Laboratory Transducer Calibration Platform at Lake Seneca, New York.

## PURPOSE OF TEST

The purpose of this test was to verify the mechanical and electrical integrity of the TR-11F elements when operating into a water load with a maximum spring deflection of 22 thousandths of an inch peak to peak.

## EXPERIMENTAL PROCEDURE

Four TR-11F transducer elements were mounted in the center of a plane array of 28 TR-11C elements as illustrated in figure 2. A front view of the experimental array at the test site is shown in figure 3. The inactive TR-11C elements were intended to serve as an acoustic

baffle in order to increase the acoustic loading on the active TR-11F elements. The elements were electrically connected as shown in figure 4. Polarizing current was applied to the inactive elements and shorting capacitors connected across their outputs in order to increase their effective mass. No pressure release material was used, thus permitting acoustic radiation from both sides of the plane array.

Each TR-11F element was instrumented with two accelerometers attached to the inner mass and one accelerometer attached to the outer mass. The inner accelerometers were located near the top and bottom edges of the internal mass and the external accelerometer was attached at the center of one radiating face. By converting the measured accelerations to displacements and vectorially adding each internal displacement to the external displacement, a measure of spring deflections at the top and bottom of the element were obtained.

The array was submerged on a pipe string to a depth of 100 feet to its center. A receiving hydrophone was suspended at a horizontal range of ten meters.

With an electrical power input to the four TR-11F elements of approximately 250 watts, the array was driven at five cycles per second increments of frequency from 350 to 450 cycles per second and at ten cycles per second increments from 450 to 500 cycles per second. Frequency, power, ac current and voltage, polarizing current and voltage, hydrophone output, and accelerometer phases and amplitudes were measured and recorded at each frequency. The measurement of polarizing voltage and current into the active elements permitted the element coil temperature to be monitored. Directivity patterns were obtained by rotating the projector in ten degree increments of azimuth.

The transducer fatigue test was initiated by driving the array at 425 cycles per second at increasing power inputs until one computed spring deflection equaled approximately 22 thousandths of an inch peak to peak. The array was then operated for $10^7$ cycles, maintaining a nearly constant maximum deflection. At twenty minute intervals the time, frequency, power, ac current and voltage, polarizing current and voltage, hydrophone output, and accelerometer phases and amplitudes were measured and recorded.

The acoustic loading on the four element array was computed as the ratio of the measured radiated power to that power which would be radiated by a rigid plane piston operating into a unity ρc load, having an area equal to that of the eight radiating faces of the four elements, and having a uniform displacement amplitude equal to the root-mean-square value of the various displacement amplitudes of the individual elements.

Although accelerometer instrumentation was provided on all four of the TR-11F elements, one internal accelerometer and the external accelerometer on element number one both developed short circuits at the beginning of the tests. The remaining internal accelerometer on element number one displayed a very distorted waveform. Consequently, no displacement data is available for element number one.

## RESULTS

The frequency characteristics of the TR-11F elements were investigated over the range from 350 to 500 cycles per second. Neither the input current nor power was held constant as the frequency was changed. However, the power was maintained between the limits of 46 to 280 watts. The polarizing current into the group of four parallel connected TR-11F elements was held constant at 7.42 amperes. The intended polarizing current was 6.6 amperes. The larger value of current was used in the test due to an instrumentation error resulting from an excessively high meter lead resistance. The instrumentation error was corrected and the current reduced to 6.60 amperes prior to an endurance test of the elements. Since the number of turns in the magnet coils of the TR-11F elements is six times that of the TR-11C's, the proper polarizing current is one-sixth of the ten amperes required by the TR-11C elements. A group of four elements in parallel therefore requires 6.6 amperes polarizing current.

The internal and external mass displacement amplitudes, normalized to [illegible] ampere alternating current input, are plotted in figures [illegible] 7 and 9 with coinciding relative phase angles plotted in figures [illegible] and 10. The corresponding spring deflections are illustrated in figures 11, 12 and 13 and the efficiency and acoustic loading in figures 14 and 15, respectively. The vector impedance locus is shown in figure 16. [illegible] resonant frequency is reduced by the [illegible] [illegible] polarizing current [illegible] amperes [illegible]

considerably higher reactive component of impedance at 425 cycles per second. Directivity patterns of the experimental array at frequencies of 350, 375, 400, 425, 450, 475 and 500 cycles per second are illustrated in figures 17 through 23

The linearity of these elements with respect to input power is illustrated in figures 24, 26 and 28 in which mass displacement amplitudes are plotted, and in figures 30, 31 and 32, plots of corresponding spring deflections. The coinciding displacement phases are illustrated in figures 25, 27 and 29. The dotted lines in these illustrations represent repeated data for which the polarizing current had been reduced from 7.92 to 6.60 amperes. Figure 33 is a plot of the impedance of the four parallel connected elements and figures 34 and 35 illustrate the corresponding values of acoustic loading and efficiency, respectively

The final experiment consisted of an endurance test in which the array was operated for six and one-half hours at 425 cycles per second. The maximum spring deflection was maintained at an amplitude of approximately 22.5 thousandths of an inch, peak to peak. The polarizing current was held constant at 6.6 amperes. Four and one half hours of continuous operation were accomplished on 22 November and the remaining two hours of continuous operation were performed on 25 November. During the intervening time the array remained submerged but was not operated.

The impedance, acoustic loading, and efficiency of the array are plotted in figures 36, 37 and 38, respectively. During the run, the input power was varied slightly in order to maintain the maximum spring deflection at an approximately constant amplitude. The input power is plotted in figure 39. The mass displacements are illustrated in figures 40, 42 and 44 with coinciding phase plots in figures 41, 43 and 45. The corresponding spring deflections are plotted in figure 46. The coil temperature, as determined from the polarizing voltage and current, is plotted in figure 47. The water temperature was 49° F. The slightly higher starting temperatures illustrated in figure 47 are the result of the application of polarizing power for a few minutes prior to excitation

CONCLUSIONS

During all tests, the waveforms of the exciting current and of all accelerometer outputs were monitored. No significant distortion was

observed except for the one remaining accelerometer on element number one as previously noted. The distortion from element number one appeared to be due to a defect in the accelerometer. At the completion of all underwater tests, the impedance in air, as a function of frequency, was measured for each of the four TR-11F elements. No significant change was observed when these measurements were compared with those made by the manufacturer prior to the underwater tests. None of the data presented in this report indicates damage to any of the elements. In light of the above, it is concluded that the elements tested are satisfactory for operation at spring deflections as high as those observed in these tests.

CONFIDENTIAL

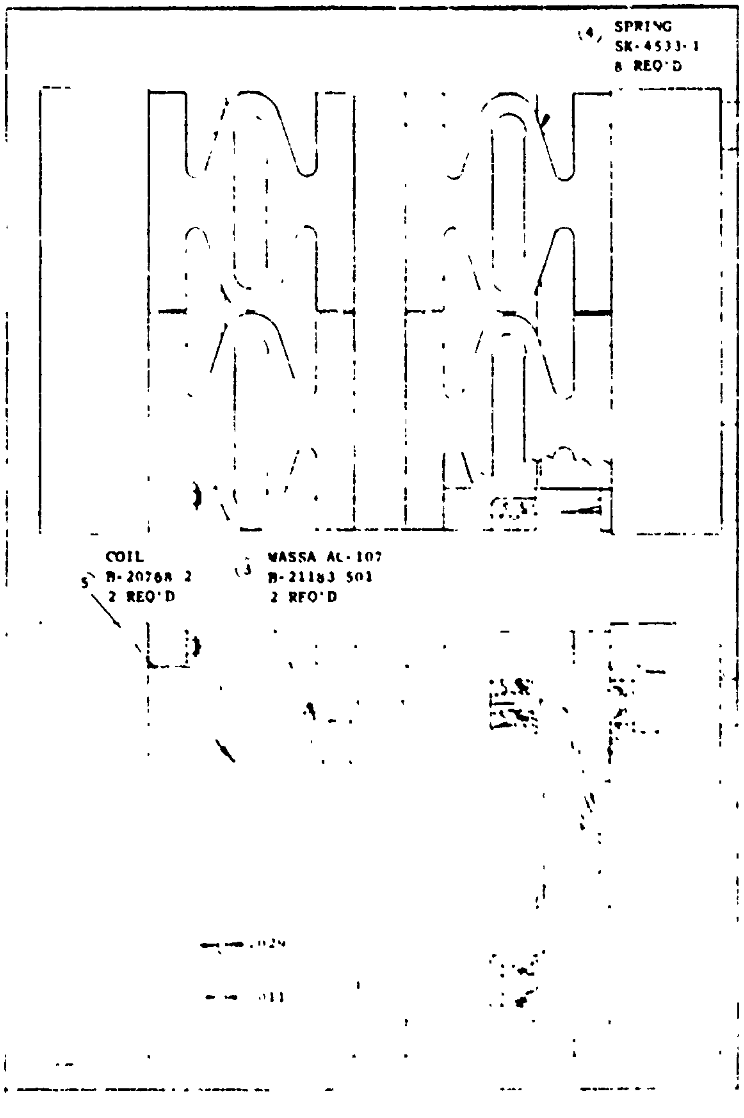



Figure 1 - Drawing of 1R-11F element with side plates removed, showing configuration of springs, air gap, and internal accelerometers

CONFIDENTIAL

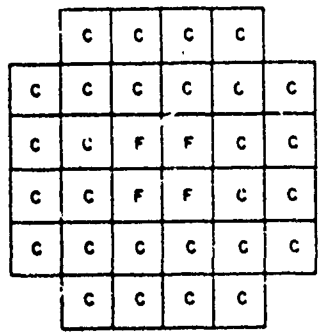



Figure 2 - Experimental transducer array containing four TR-11F elements in a baffle of 28 TR-11C elements

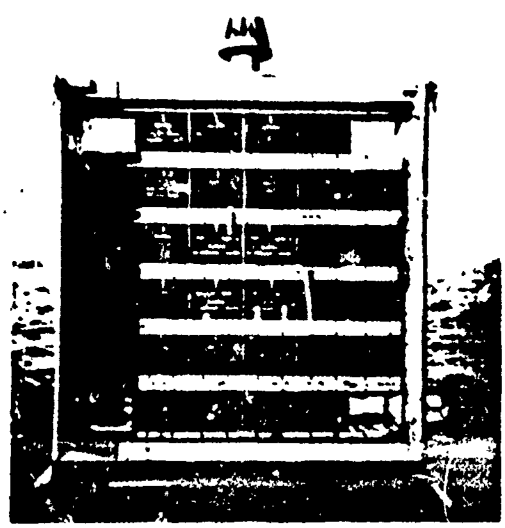


Figure 3 - Front view of experimental array

CONFIDENTIAL

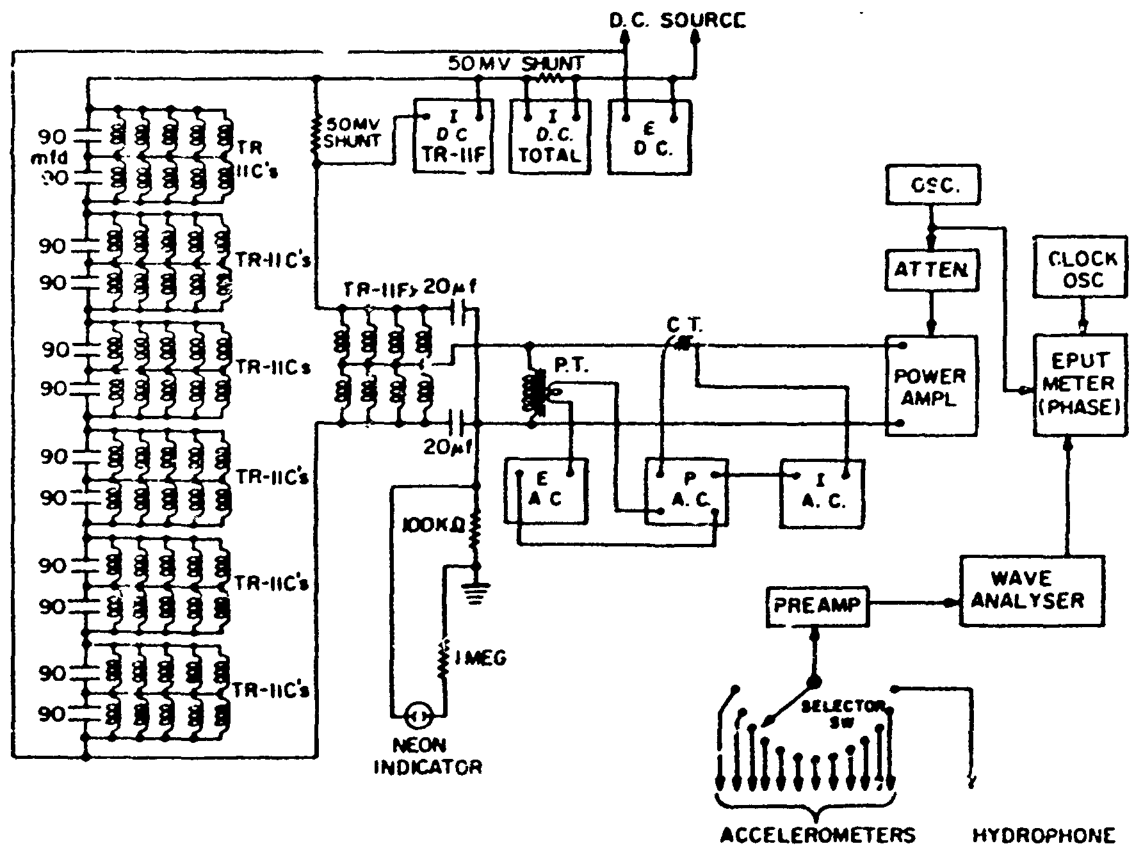



Figure 4 - Experimental instrumentation

CONFIDENTIAL

CONFIDENTIAL

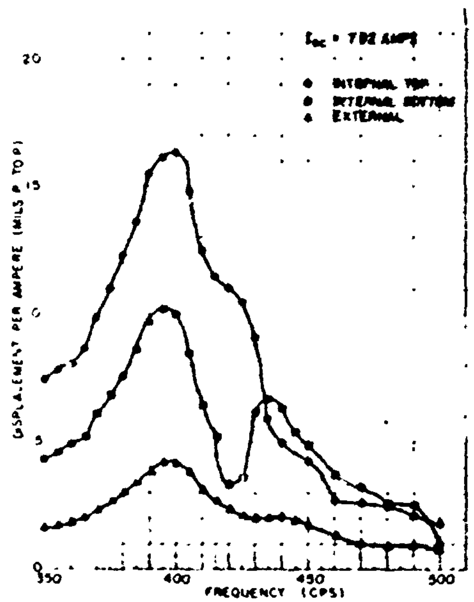



Figure 5 - Frequency dependence of internal and external mass displacement amplitudes normalized to one ampere ac input for element number 2

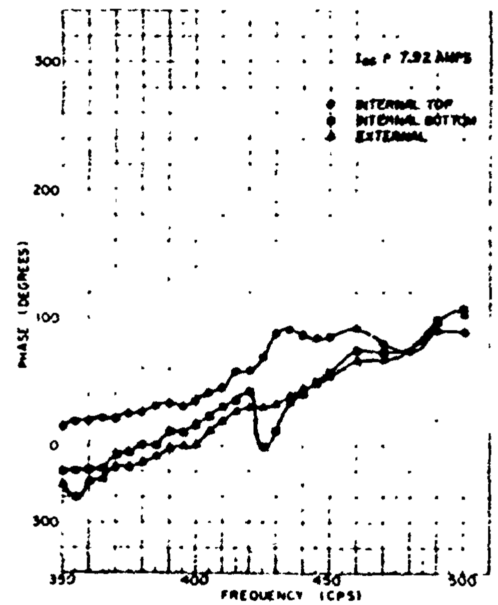



Figure 6 - Frequency dependence of displacement phase for element number 2

CONFIDENTIAL

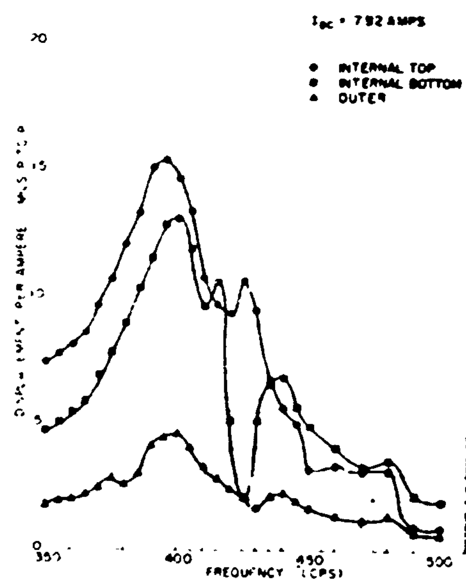



Figure 7 - Frequency dependence of internal and external mass displacement amplitudes normalized to one ampere ac input for element number 3

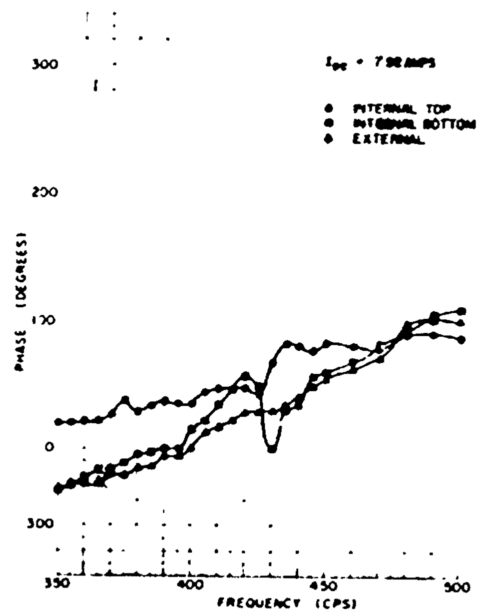



Figure 8 - Frequency dependence of displacement phase for element number 3

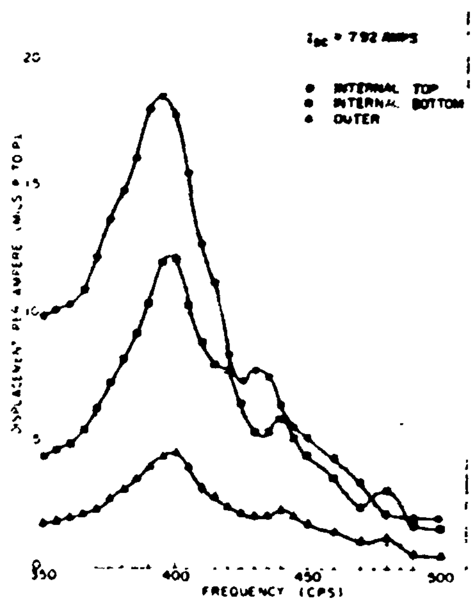



Figure 9 - Frequency dependence of internal and external mass displacement amplitudes normalized to one ampere ac input for element number 4

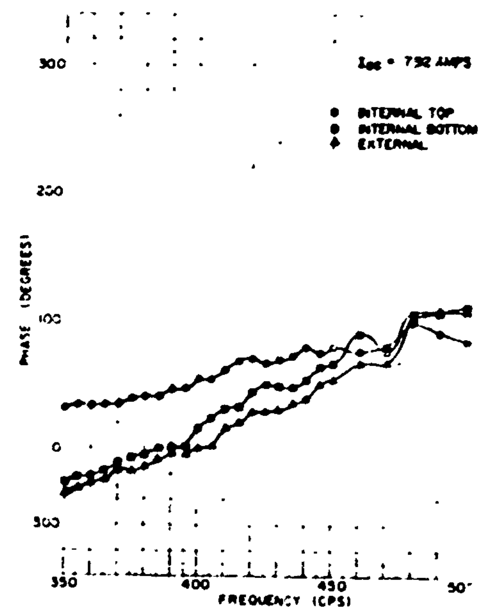



Figure 10 - Frequency dependence of displacement phase for element number 4

CONFIDENTIAL

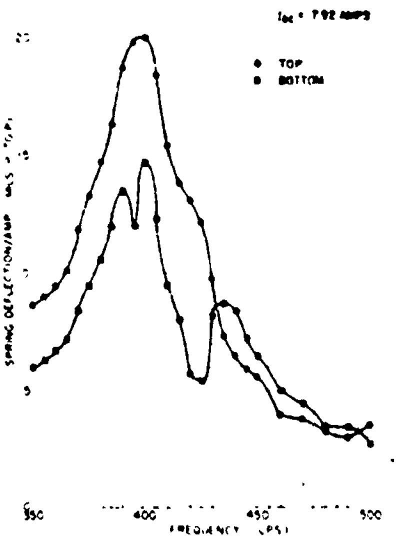



Figure 11 - Frequency dependence of spring deflections normalized to one ampere ac input. Element number 2.

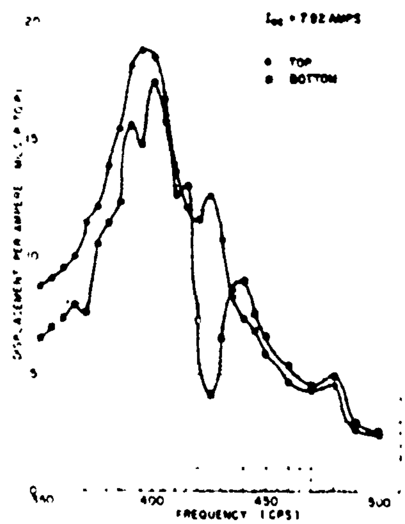



Figure 12 - Frequency dependence of spring deflections normalized to one ampere ac input. Element number 3.

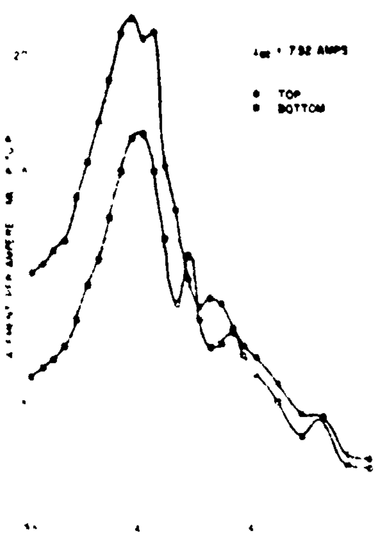



Figure 13 - Frequency dependence of spring deflections normalized to one ampere ac input. Element number 4.

CONFIDENTIAL

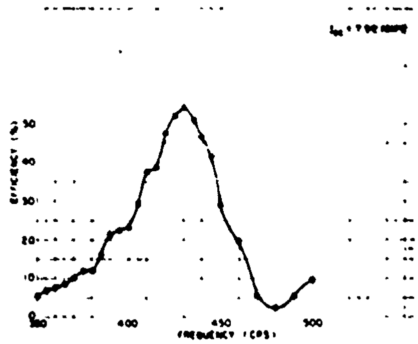
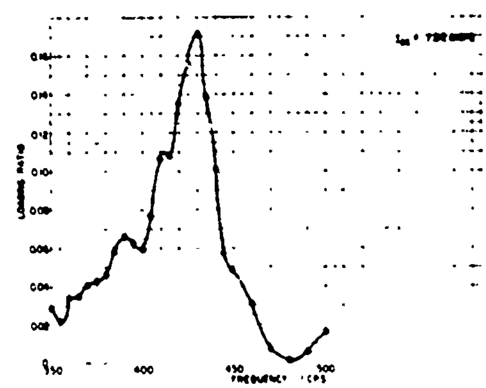


Figure 14 - Frequency dependence of efficiency of four element array

Figure 15 - Frequency dependence of loading ratio of four element array



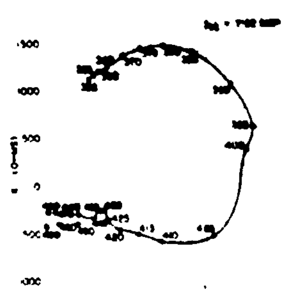
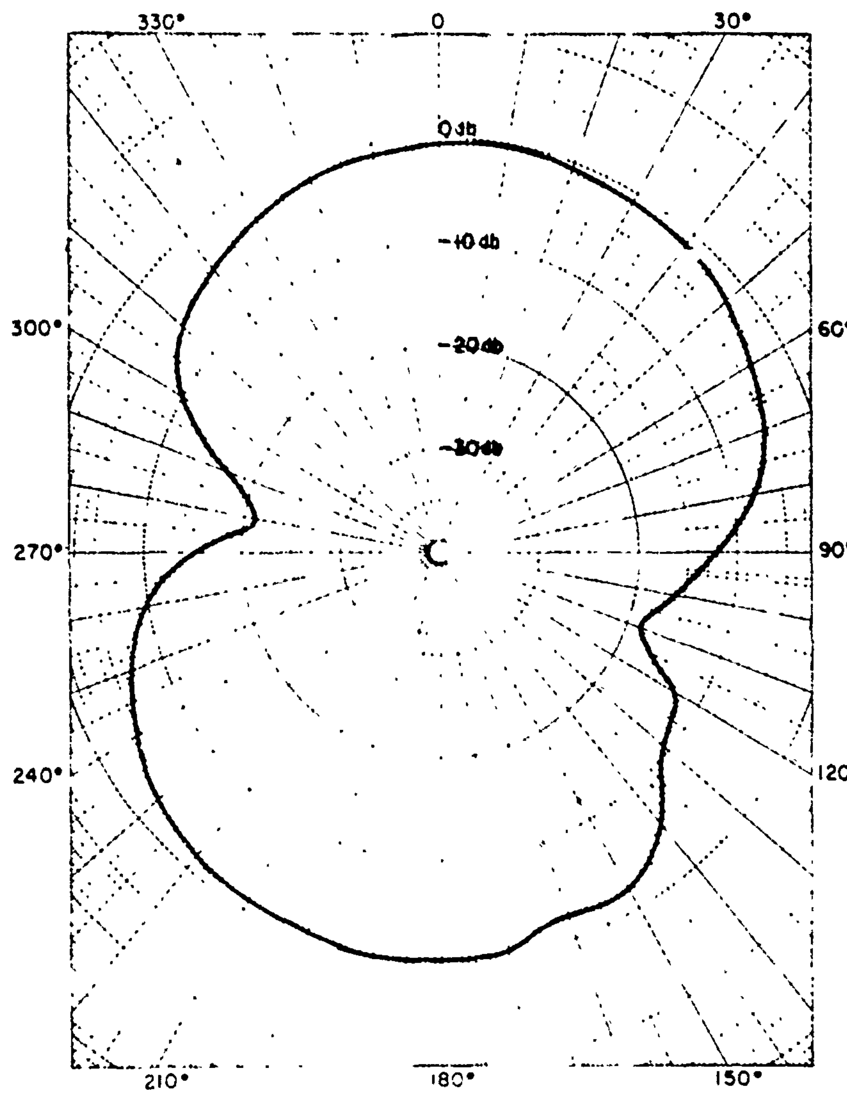


Figure 16 - Vector impedance locus diagram for four element array

CONFIDENTIAL




CONFIDENTIAL

CONFIDENTIAL

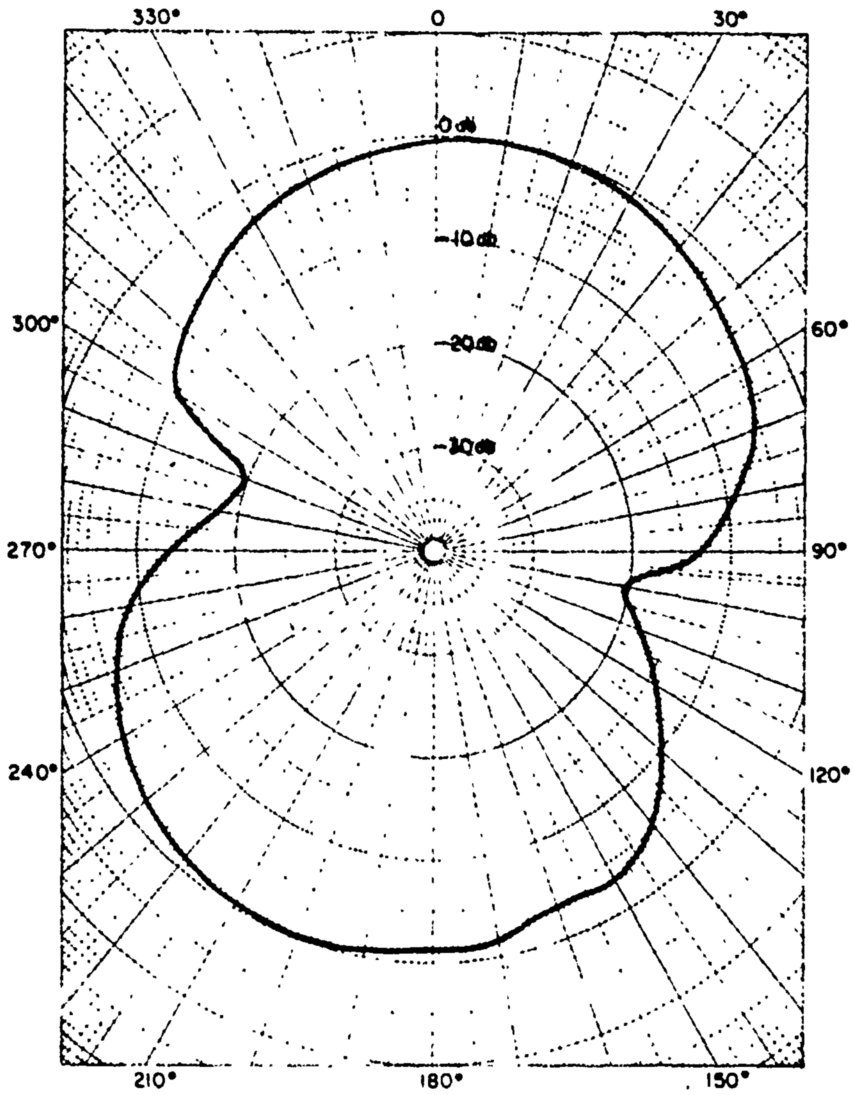
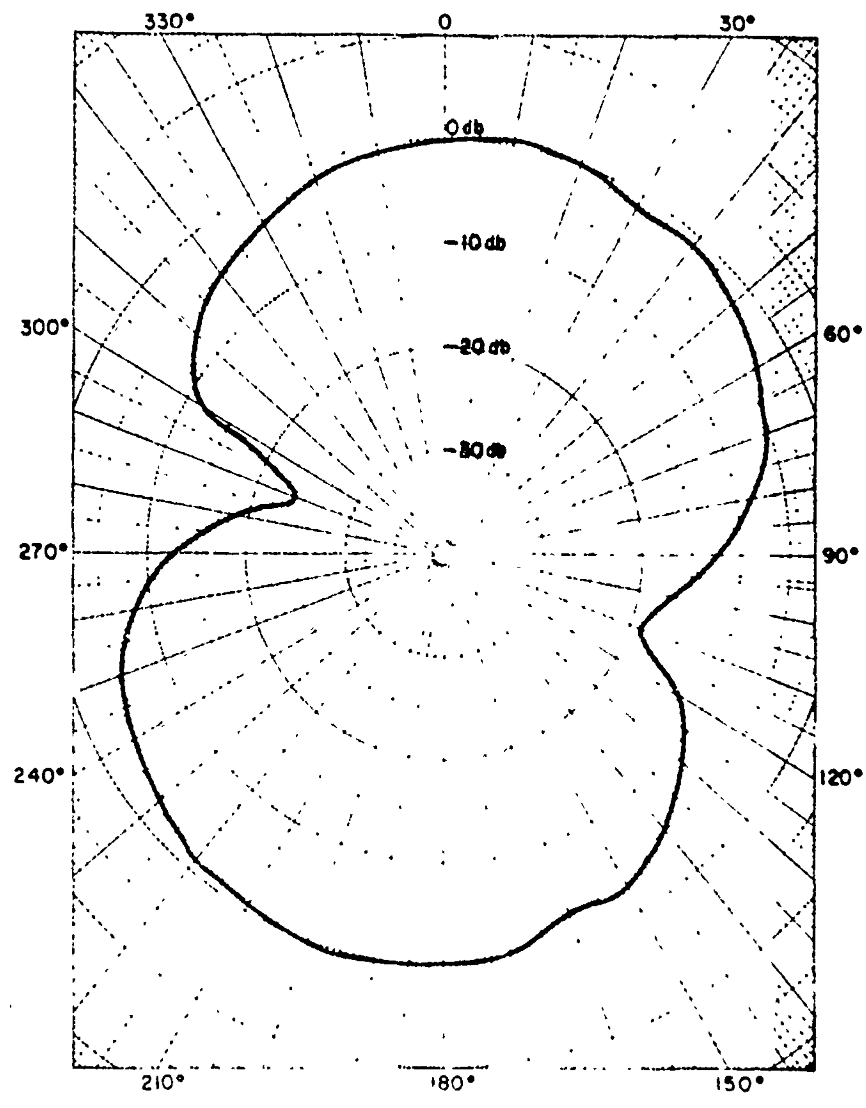



Figure 18 - Directivity pattern - 375 cps

CONFIDENTIAL

CONFIDENTIAL




[illegible] = 400 cps CONFIDENTIAL

CONFIDENTIAL

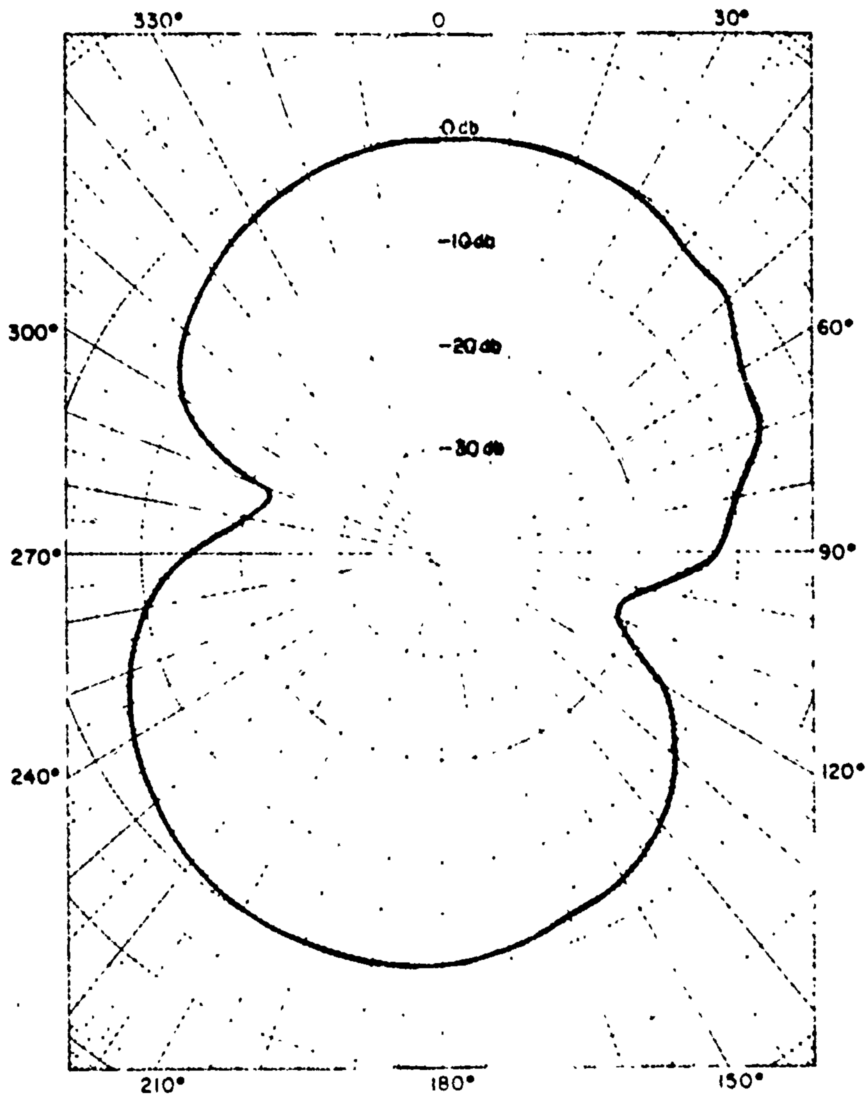



Figure 2c - Directivity [illegible] - [illegible] cps CONFIDENTIAL

CONFIDENTIAL

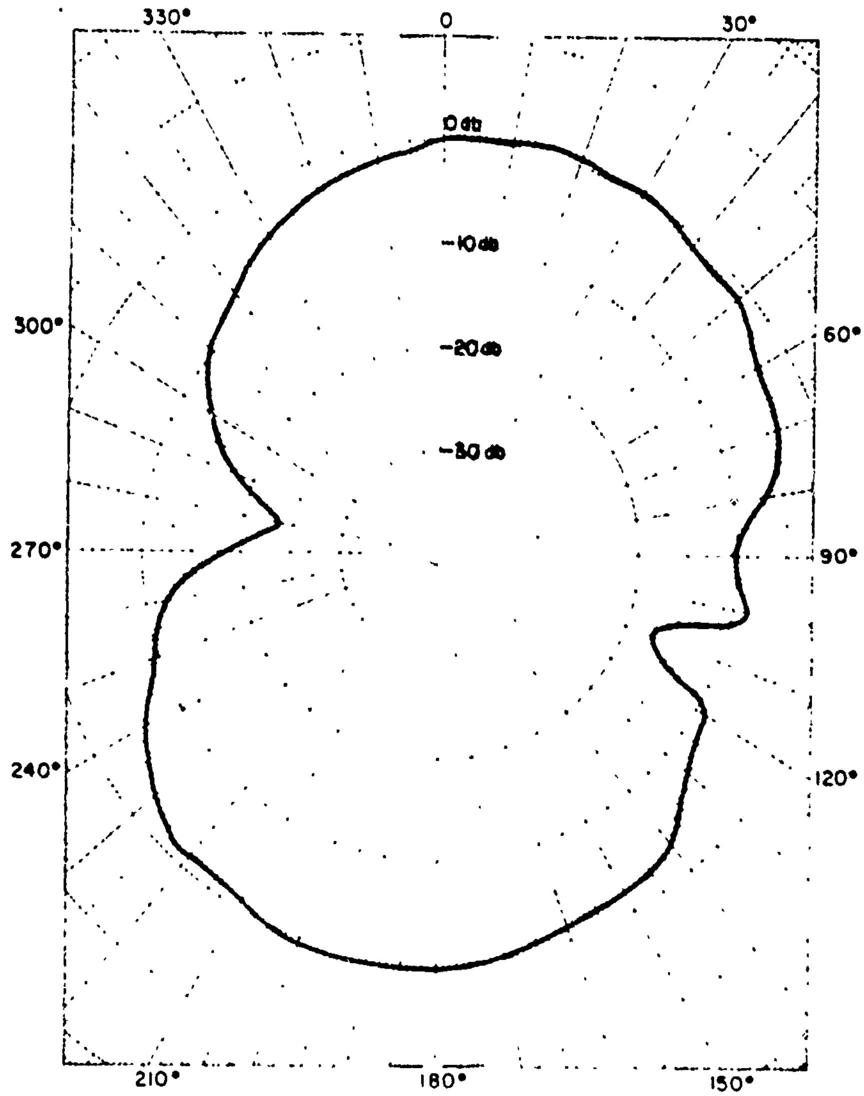



Fig. 21 - Directivity pattern - 450 cps

CONFIDENTIAL

CONFIDENTIAL

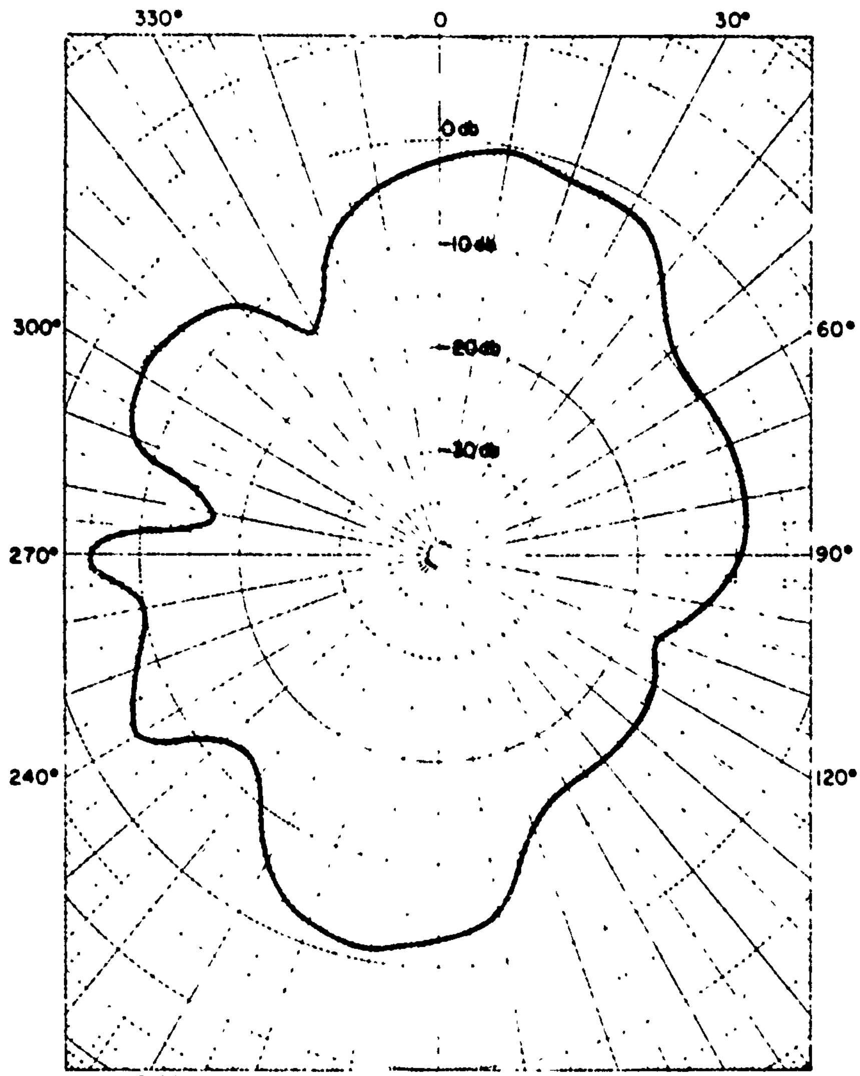



Figure 22 - Directivity pattern - 475 cps

CONFIDENTIAL

CONFIDENTIAL

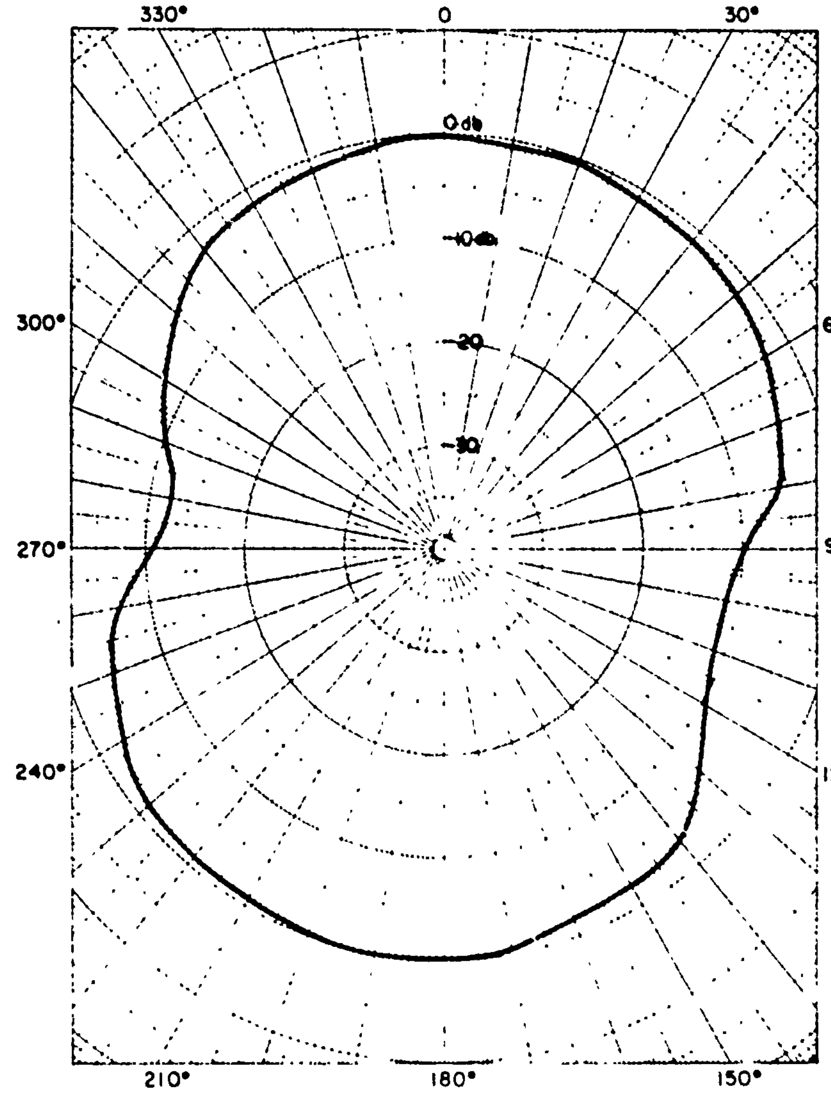



Figure 25 - Directivity pattern - 500 cps

CONFIDENTIAL

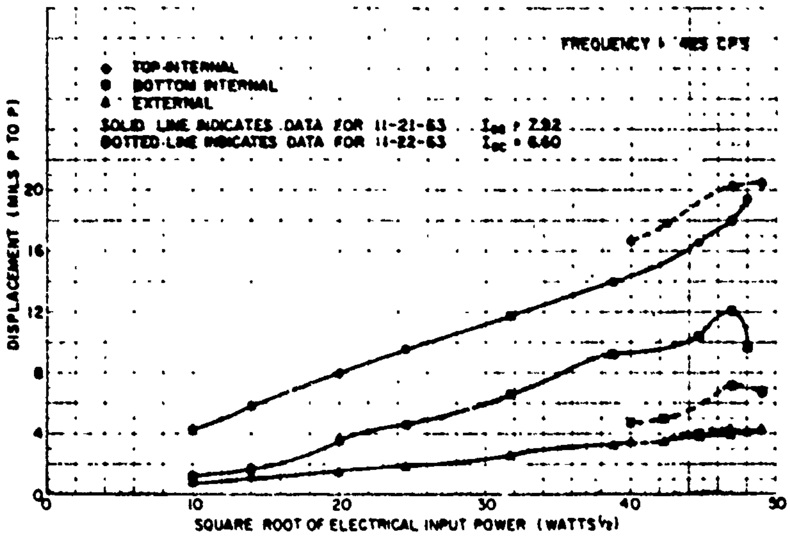



Figure 24 - Displacement amplitude linearity with input power for element number 2

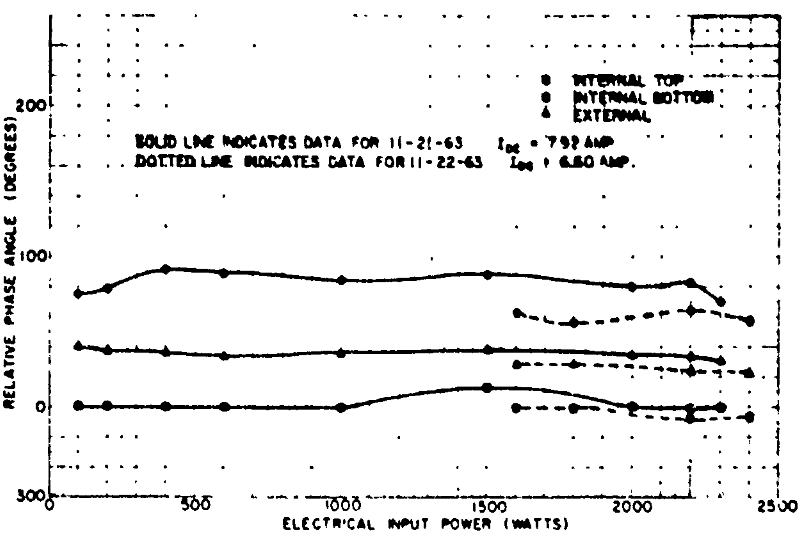



Figure 25 - Displacement phase stability with input power for element number 2

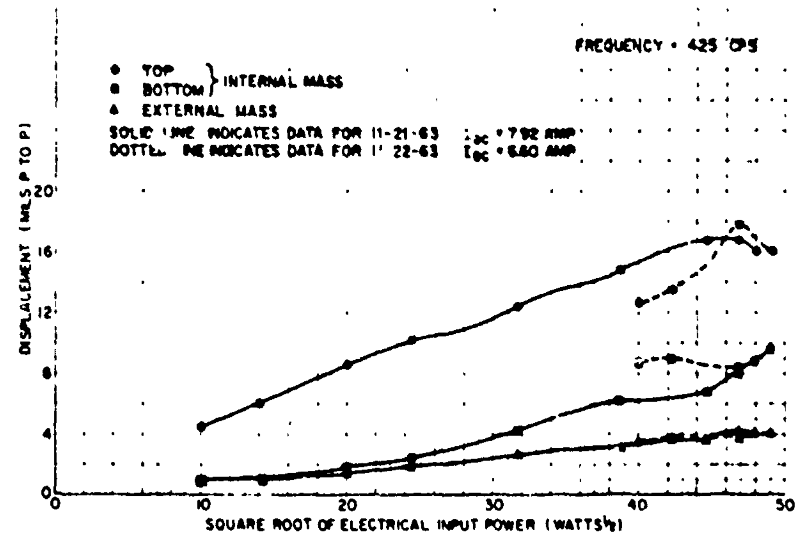



Figure 26 - Displacement amplitude linearity with input power for element number 3

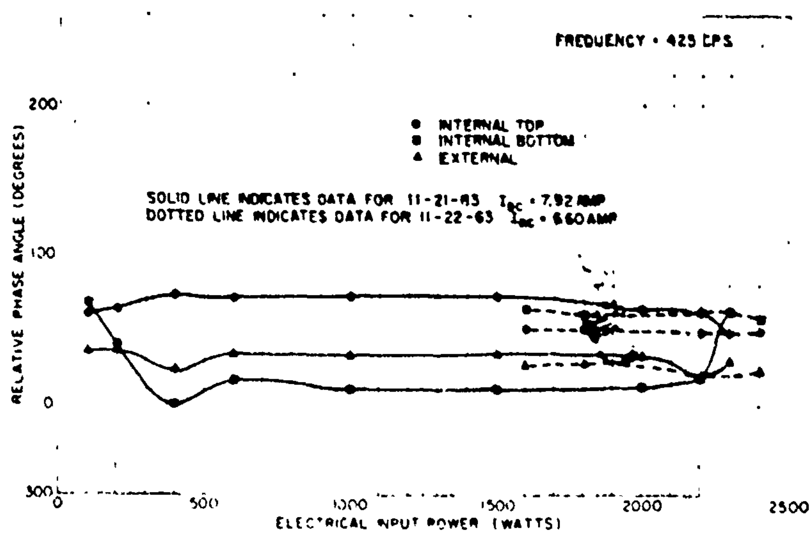



Figure 27 - Displacement phase stability with input power [illegible]

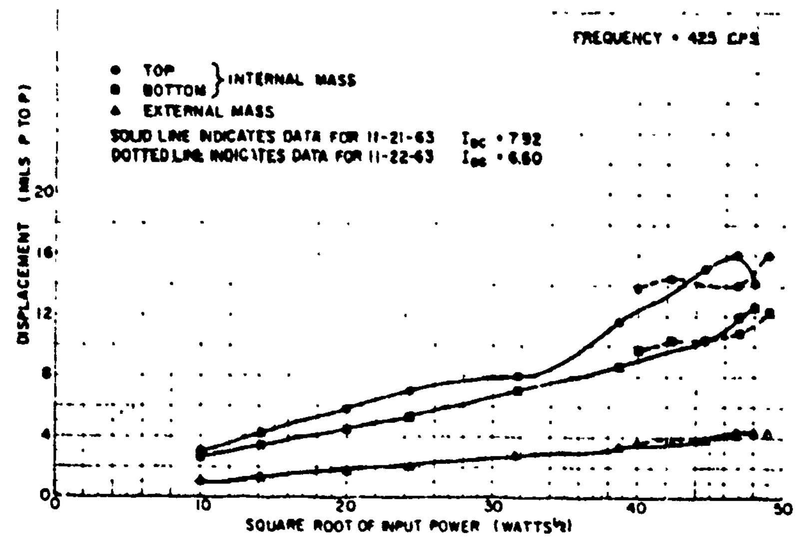



**Figure 28 - Displacement amplitude linearity with input power for element number 4**

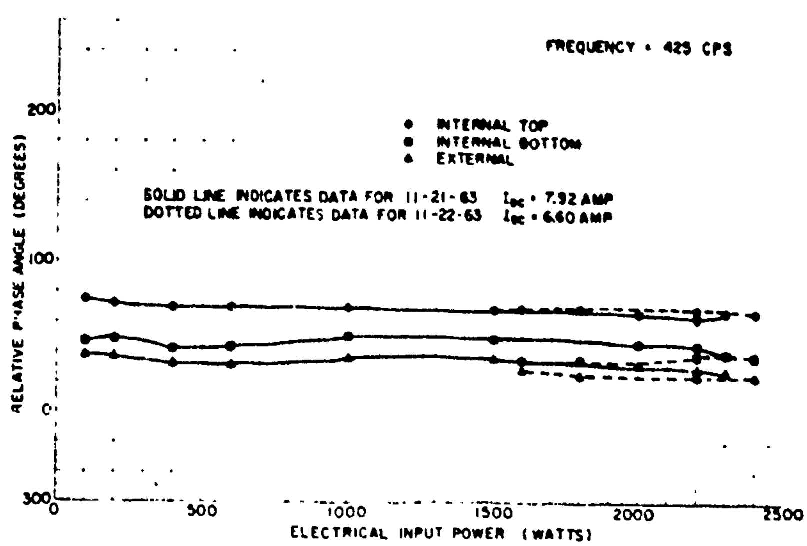



Figure 29 - Displacement phase stability with input power for element number 4

CONFIDENTIAL

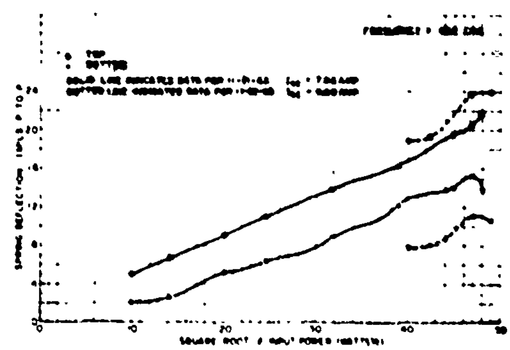


Figure 30 - Spring deflection linearity with input power - element number 2

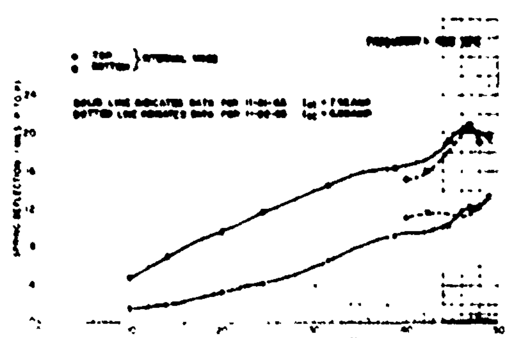


Figure 31 - Spring deflection linearity with input power - element number 3

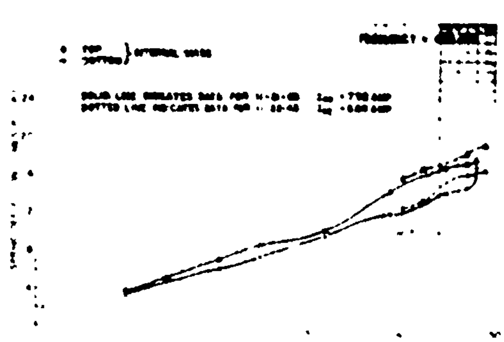


Figure 32 - Spring deflection linearity with input power - element number 4

CONFIDENTIAL

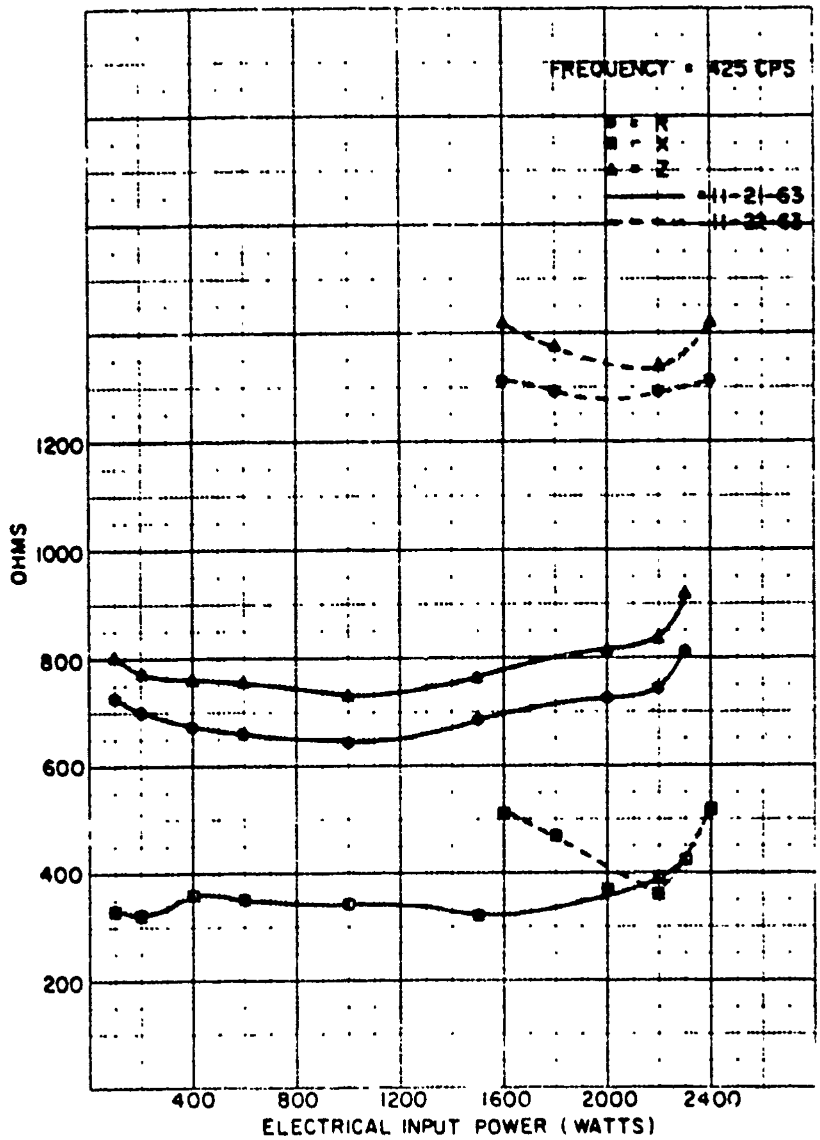



Figure 33 - Dependence of impedance on input power

CONFIDENTIAL

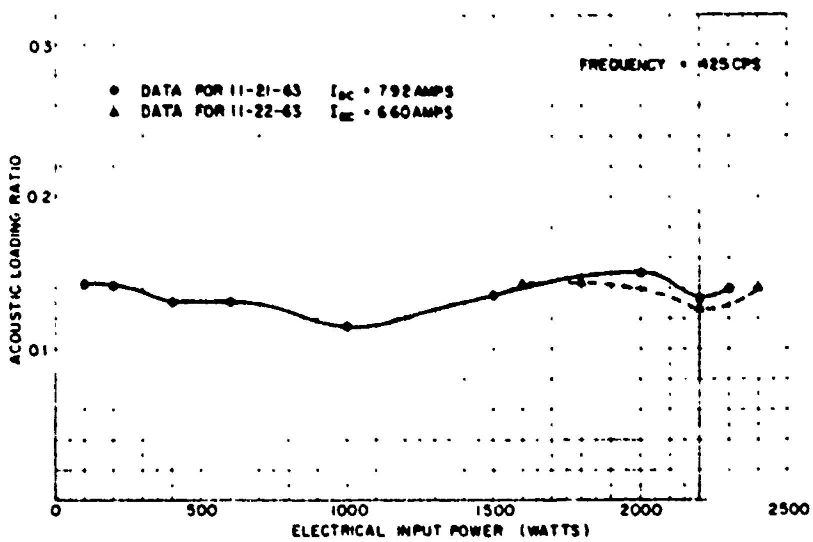



Figure 34 - Dependence of acoustical loading ratio on input power

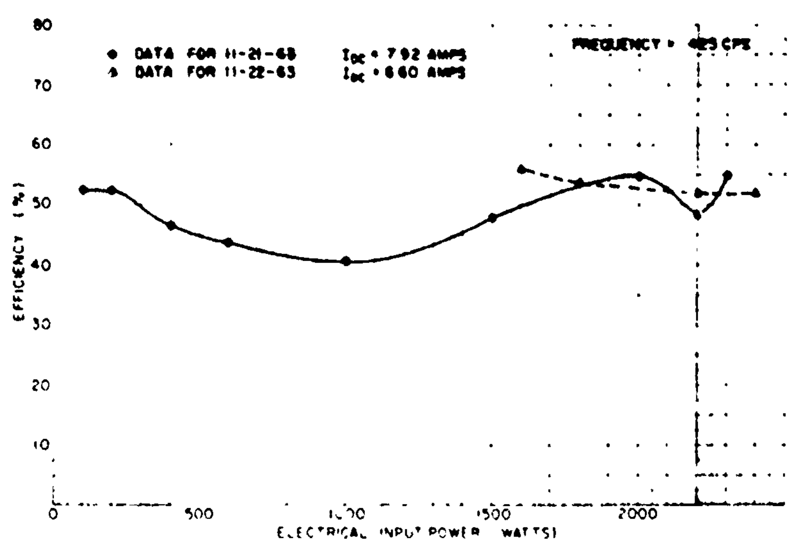



Figure 35 - Dependence of efficiency on input power

CONFIDENTIAL

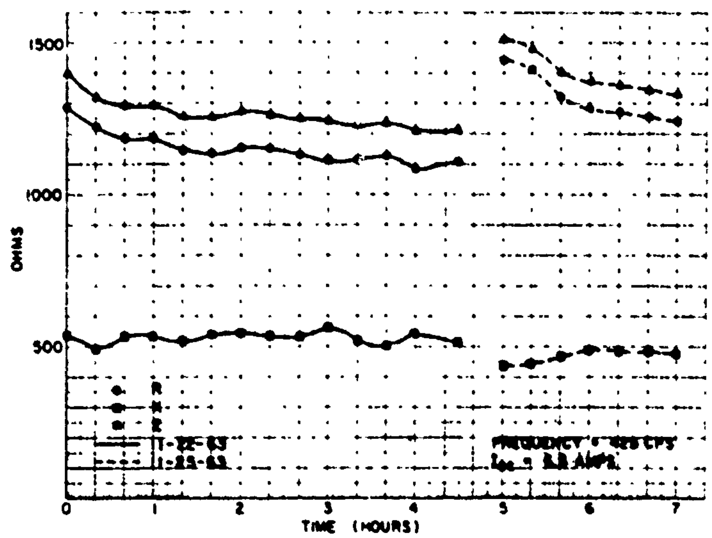



Figure 36 - Array impedance during endurance test

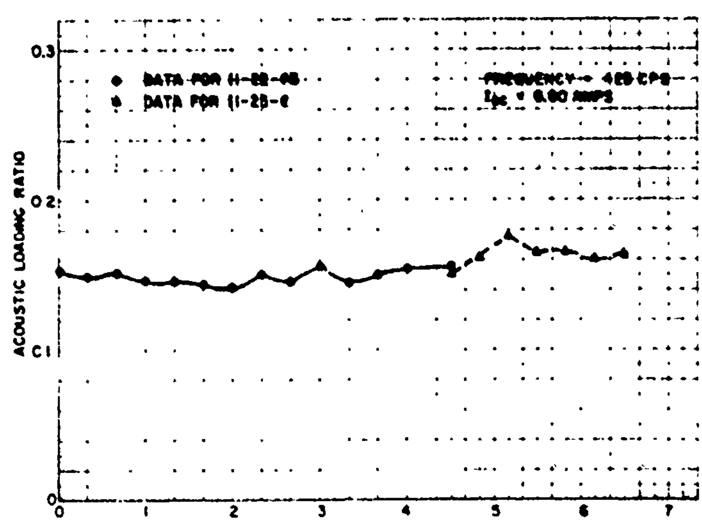



Figure 37 - Acoustic loading ratio during endurance test

CONFIDENTIAL

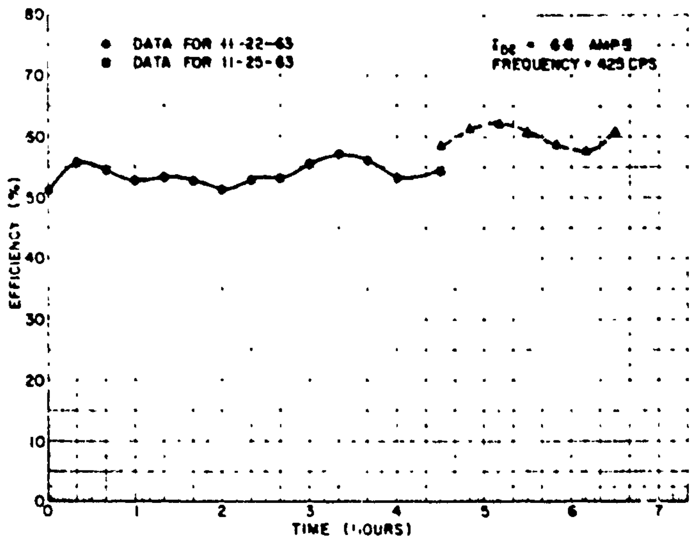



Figure 38 - Array efficiency during endurance test

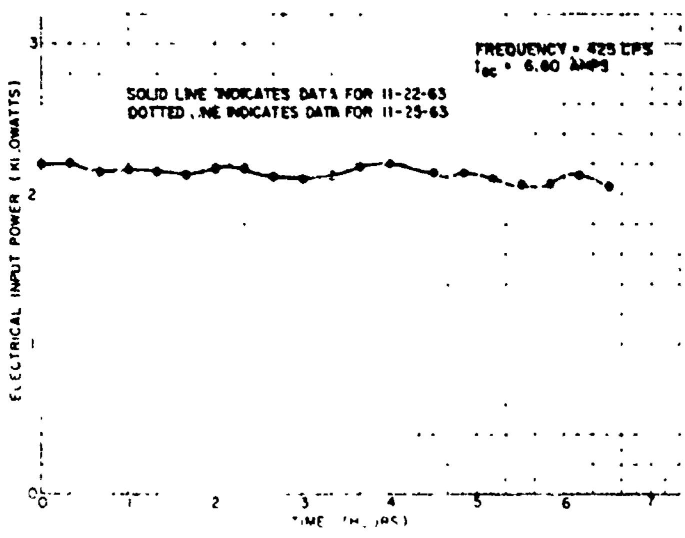



Figure 39 - Electrical input power during endurance test

CONFIDENTIAL

CO! FIDENTIAL

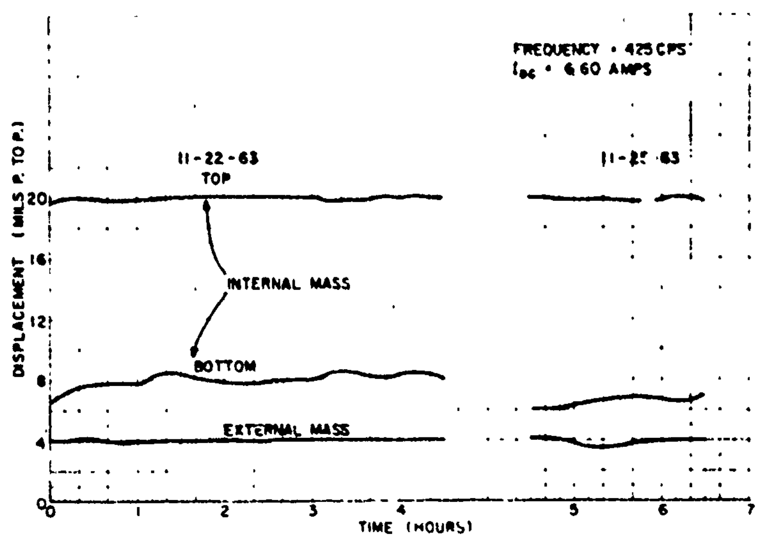



**Figure 40 - Internal and external mass displacement amplitudes during endurance test for element number 2**

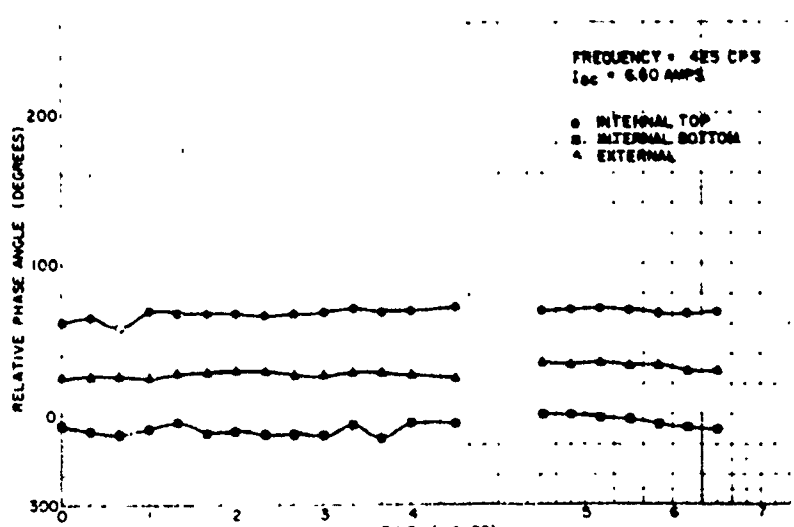



Figure 41 - Displacement phase during endurance test for element number 2

CONFIDENTIAL

[redacted]

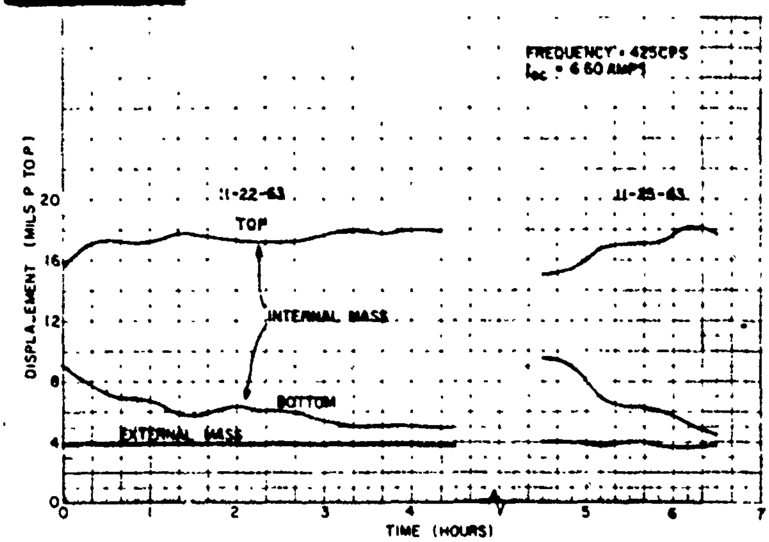



Figure 42 - Internal and external mass displacement amplitudes during endurance test for element number 3

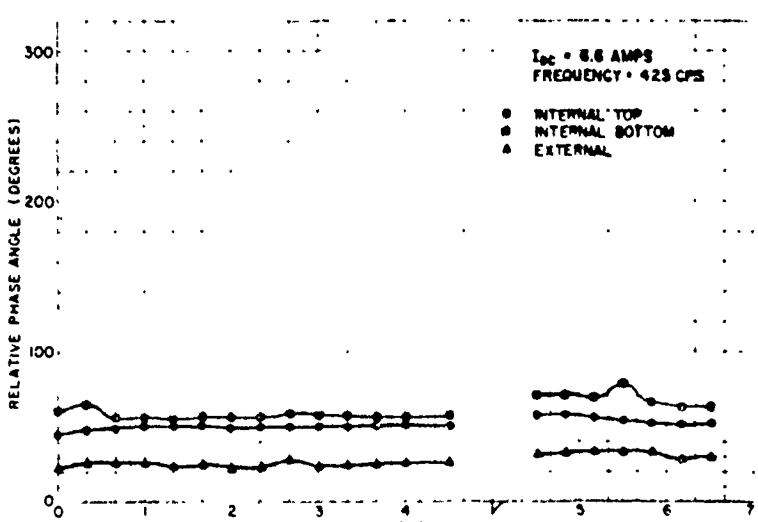



Figure 43 - Displacement phase during endurance test for element number 3

[redacted]

[redacted]

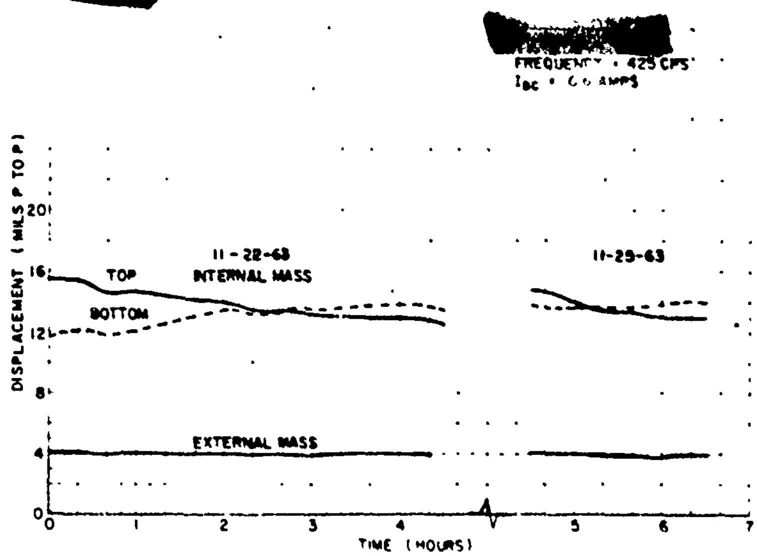



Figure 44 - Internal and external mass displacement amplitudes during endurance test for element number 4

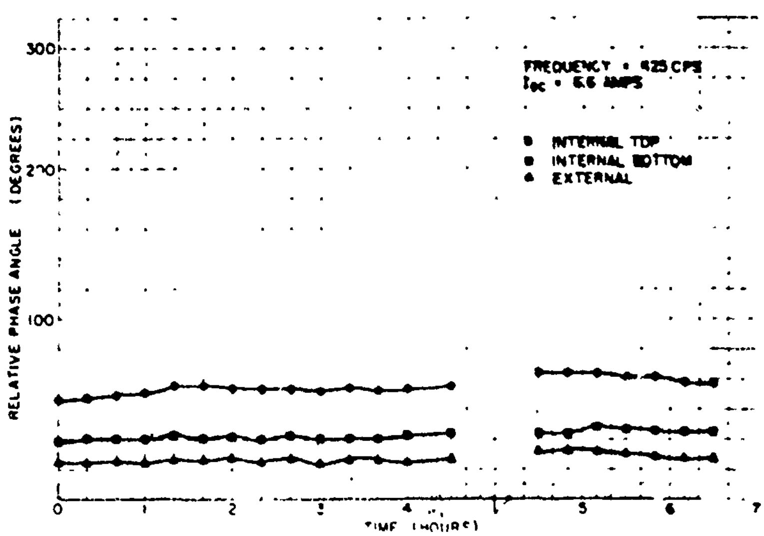



Figure 45 - Displacement phase during endurance test for element number 4

[redacted] [redacted]

[redacted]

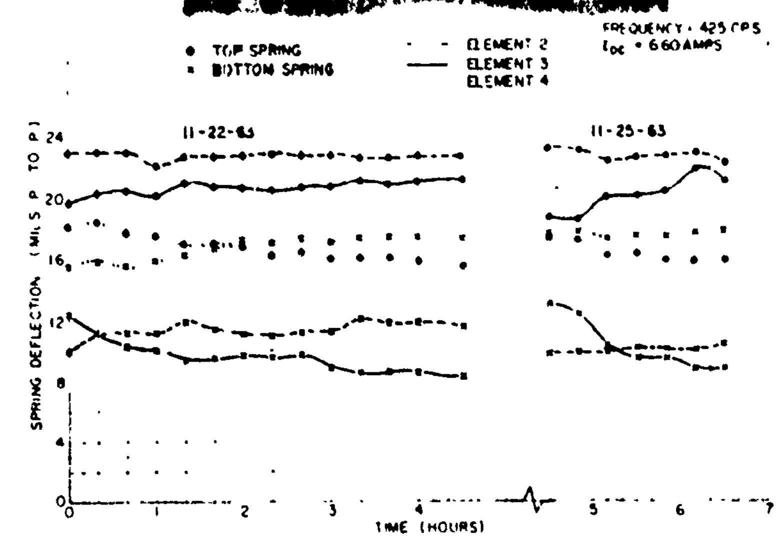
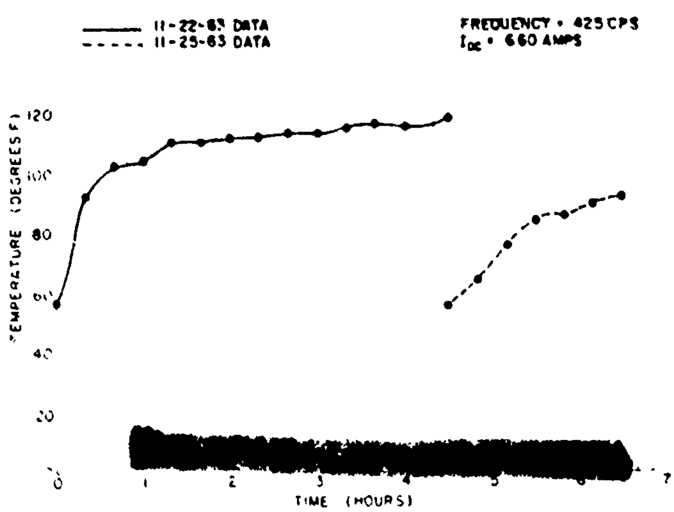



Figure 46 - Spring deflections during endurance test




[redacted]